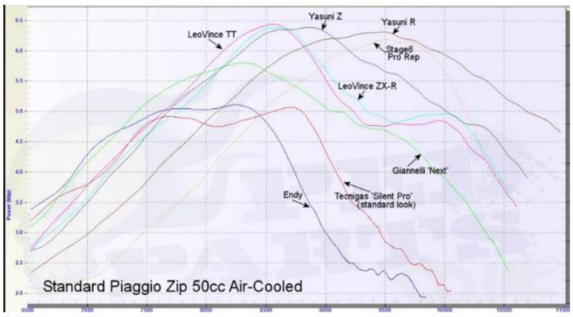
Corresponding power curves



Chapter 15 – Crankshaft

15.1 Introduction

The crankshaft's function is to transmit the energy created by the combustion chamber through the piston and transform it into motion. This energy is then transmitted through the crankshaft to the gears or belts, all the way to the wheel itself.

The quality of the crankshaft's moving assembly, which consists of pins and bearings, including the connecting rod, is vital to the engine's longevity and reliability. That's why we need to assess the health of this assembly and ensure its integrity before considering any modifications. Whenever possible, opt for original connecting rods and bearings or those from renowned brands in the manufacture of performance components. Using questionable parts here jeopardizes all the work done.

It is necessary to ensure perfect alignment and that the assembly does not contain excessive gaps.

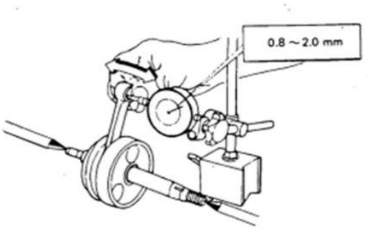
15.2 Recommendations

Let's use the RD135 service manual as a reference, which indicates the maximum acceptable clearances before deciding whether or not to replace the connecting rod assembly.

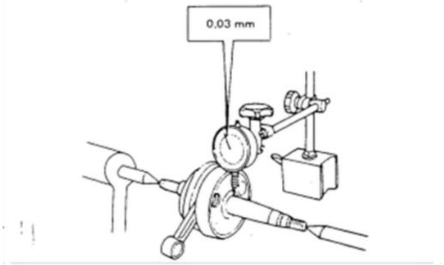
The RD has a 100mm center-to-center connecting rod and 50mm stroke.

The maximum lateral clearance at the top of the connecting rod is 2 mm. Therefore, replacing it is recommended. However, our goal is to increase engine power, and we shouldn't use a connecting rod that's close to this clearance, knowing that it will already be at the end of its useful life. I always recommend replacing it whenever we prepare the engine. Always check your motorcycle's service manual for acceptable clearances, but if you don't have one, we can use a guide, as I'll explain below.

1 – Folga axial superior da biela.
2 – Desalinhamento do virabrequim.



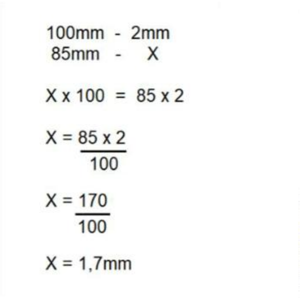
Trocar a biela, rolamento superior da biela, arruelas de encosto e o pino inferior da biela, se exceder o limite de desgaste.



Knowing that the connecting rod is 100mm and the maximum clearance is 2mm, with a simple rule of 3 we can find out, for example, the maximum clearance of a connecting rod 85mm long as shown in the photo on the side.

This way we can calculate the maximum clearance for any engine.

Another important point is crankshaft centering. The minimum centering a 50mm stroke can accept is 3 cents, and we can use the rule of 3 to determine the limit for any engine, knowing its stroke.



100mm - 2mm
85mm - X

$$X \times 100 = 85 \times 2$$

$$X = \frac{85 \times 2}{100}$$

$$X = \frac{170}{100}$$

$$X = 1{,}7\text{mm}$$

The piston pin, bearing, and upper connecting rod eye also require attention. They must not have excessive play, and there must be no signs of wear on the connecting rod, as shown in the photo below. Sanding to remove the marks won't help, as this will only increase the play. In this case, replacement is mandatory.

The holes in the connecting rod eyelet greatly help lubricate the upper cage. If the connecting rod doesn't have one, it's recommended to drill two holes in the upper part or a slot with a cutting disc and grinder. These cutting discs are less than 1 mm thick and will do an excellent job. Remember not to overheat the connecting rod during this process. It has a heat treatment that can be lost if overheated. I recommend doing this in stages, always cooling the connecting rod.

The piston cage is the biggest weak point of two-stroke engines. It bears all the pressure and heat of combustion, so it will always be the engine's weak point.

Preferably use cages from reputable brands. Don't skimp on this component, as we know it's the one that suffers most from the effects of a well-tuned engine and, in its normal state, is designed for much lower power than we want to subject it to.

It's also wise to open the engine regularly and check its condition, including the piston pin and connecting rod for wear. I also recommend replacing them after a certain period of use.

Choose cages that are more closed and prevent the roller from coming off the connecting rod, as shown in the example on the left of the image below.

A good way to tell if its good quality is to run the file along the outside of the cage. If it's good quality, the file will "scream" and won't remove material, as it should be made of good steel and tempered to a good hardness. If the file doesn't "scream" and removes material, be suspicious.

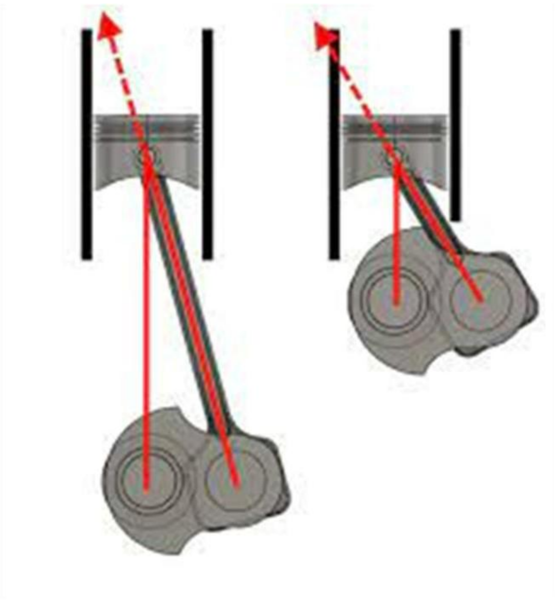
15.3 RL (connecting rod angle)

The RL is nothing more than the angle of attack of the connecting rod in relation to the cylinder. The longer the crankshaft stroke, the wider the connecting rod needs to be to minimize the effects of this excessive angle, which is increased friction between the piston and the cylinder wall.

On the side, we see two examples of identical crankshaft strokes, but different connecting rod lengths. It's clear that the longer connecting rod softens the angle and reduces the effort and friction between the piston and cylinder.

In this case, we'll always be tempted to increase the length of the connecting rod and reduce this problem. However, a longer connecting rod is heavier, not only because of its length but also because it requires greater thickness. The longer the connecting rod, the thicker it needs to be to avoid bending. A heavier connecting rod alters the dynamic balance of the crankshaft, and while we gain in reduced friction, we lose in vibrations and increased movable weight.

There's a good RL ratio that allows the engine to function properly. This ratio is between 2 and 2.2, which we'll learn how to calculate next.



The Aprilia engine was somewhat criticized for using a 120mm connecting rod, while other manufacturers used something closer to 100mm.

Fritz Overmars countered by saying that it was enough to look at the 50cc racing engines of the time that used 85mm connecting rods and a 39mm stroke, generating a RL of 2.17. RSA followed this same relationship, using 2.2.

The formula for calculation is simple, just divide the length of the connecting rod from center to center by the stroke of the crankshaft.

For example:

Aprilia had 120/54.5 = 2.2.

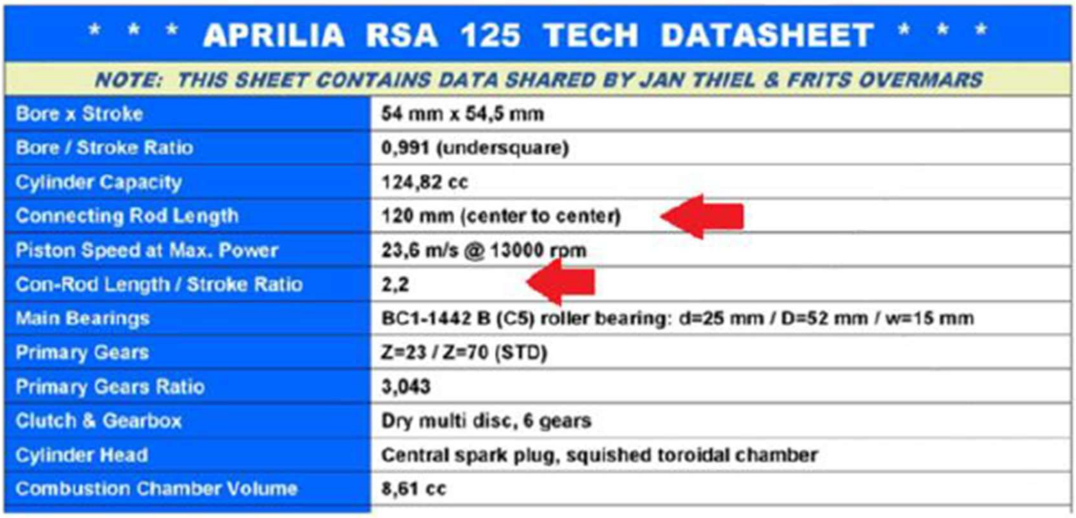
The DT200 has 110/57 = 1.92

AV-10 has 85/41.8 = 2.03.

The RD135 has 100/50 = 2.

The X30 SS has 115/54.4 = 2.11

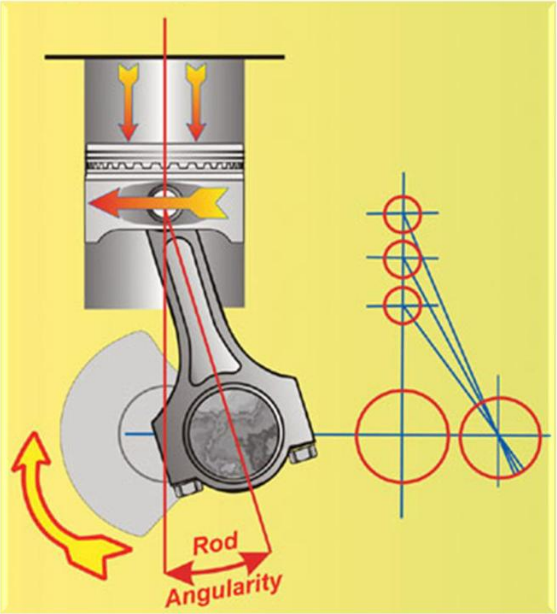
The X30 S has 104/54.4 = 1.91



* * * APRILIA RSA 125 TECH DATASHEET * * *

NOTE: THIS SHEET CONTAINS DATA SHARED BY JAN THIEL & FRITS OVERMARS

Bore x Stroke	54 mm x 54,5 mm
Bore / Stroke Ratio	0,991 (undersquare)
Cylinder Capacity	124,82 cc
Connecting Rod Length	120 mm (center to center)
Piston Speed at Max. Power	23,6 m/s @ 13000 rpm
Con-Rod Length / Stroke Ratio	2,2
Main Bearings	BC1-1442 B (C5) roller bearing: d=25 mm / D=52 mm / w=15 mm
Primary Gears	Z=23 / Z=70 (STD)
Primary Gears Ratio	3,043
Clutch & Gearbox	Dry multi disc, 6 gears
Cylinder Head	Central spark plug, squished toroidal chamber
Combustion Chamber Volume	8,61 cc

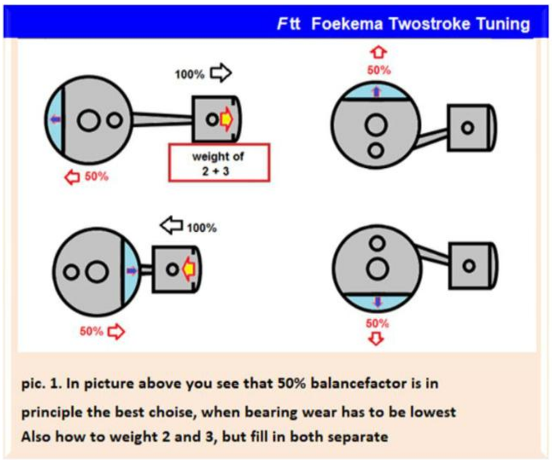


15.4 Balancing

It's generally agreed that a single-cylinder engine can't be perfectly balanced. There will always be more weight rotating or moving up and down in some direction. What can be done is to minimize excess weight in a single direction that is overriding it and reduce the stress placed on the bearings.

Second Luck Foekema, the best balance factor will be 50%, considering that there will be 50% of the mass heading in some direction and not 60 or 70%.

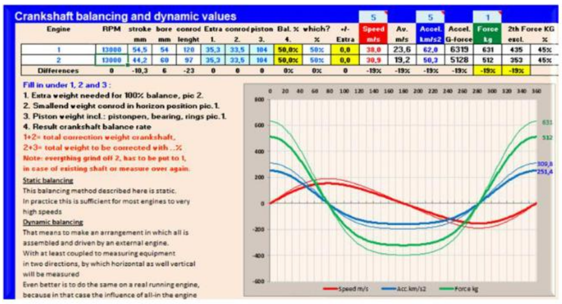
Be aware that altering the crankshaft stroke, replacing the piston with a larger one, or even a different brand alters the balance factor. Any change to the moving assembly alters the factor.



pic. 1. In picture above you see that 50% balancefactor is in principle the best choise, when bearing wear has to be lowest Also how to weight 2 and 3, but fill in both separate

Luck has a weight calculation spreadsheet that calculates bearing load based on RPM and the weight to remove or add to the crankshaft based on piston weight. Simply enter engine data such as target RPM, stroke, piston diameter, connecting rod length, measured weights, and balance percentage.

The spreadsheet tells you the bearing load in terms of weight and the crankshaft angle at which this occurs. However, we can do this calculation manually and find the best balance factor.



Crankshaft balancing and dynamic values

Engine	RPM	stroke mm	bore mm	conrod lenght	Extra 1.	conrod 2.	piston 3.	Bal. % 4.	which? %	+/- Extra	5 Speed m/s	Av. m/s	5 Accel. km/s2	Accel. G-force	1 Force kg	2th Force KG excl.	%
1	13000	54,5	54	120	35,3	33,5	104	50,0%	50%	0,0	38,0	23,6	62,0	6319	631	435	45%
2	13000	44,2	60	97	35,3	33,5	104	50,0%	50%	0,0	30,9	19,2	50,3	5128	512	353	45%
Differences	0	-10,3	6	-23	0	0	0	0%	0%	0	-19%	-19%	-19%	-19%	-19%	-19%	

Fill in under 1, 2 and 3 :
1. Extra weight needed for 100% balance, pic 2.
2. Smallend weight conrod in horizon position pic. 1.
3. Piston weight incl.: pistonpen, bearing, rings pic. 1.
4. Result crankshaft balance rate
1+2= total correction weight crankshaft,
2+3= total weight to be corrected with ..%
Note: everything grind off 2, has to be put to 1,
in case of existing shaft or measure over again.

Static balancing

This balancing method described here is static.
In practice this is sufficient for most engines to very high speeds

Dynamic balancing

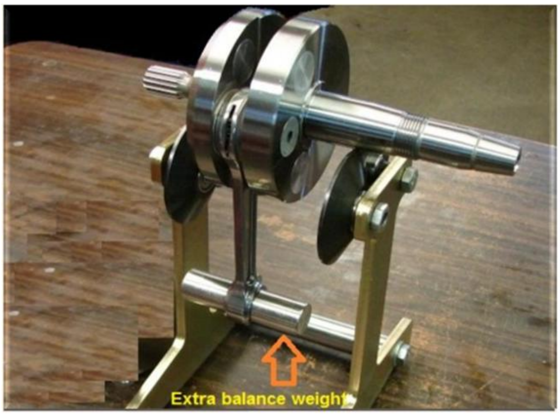
That means to make an arrangement in which all is assembled and driven by an external engine.
With at least coupled to measuring equipment in two directions, by which horizontal as well vertical will be measured
Even better is to do the same on a real running engine, because in that case the influence of all-in the engine

But we need to understand that it's difficult to change the balance factor of an assembly, as it requires adding or removing weight from somewhere. This includes cutting, drilling, welding, and even adding tungsten or lead to the crankshaft.

The first step is to determine the current balance factor of the assembly and then begin adjustments to achieve the desired 50% balance factor. The first step is to measure the connecting rod weight and record all the data.

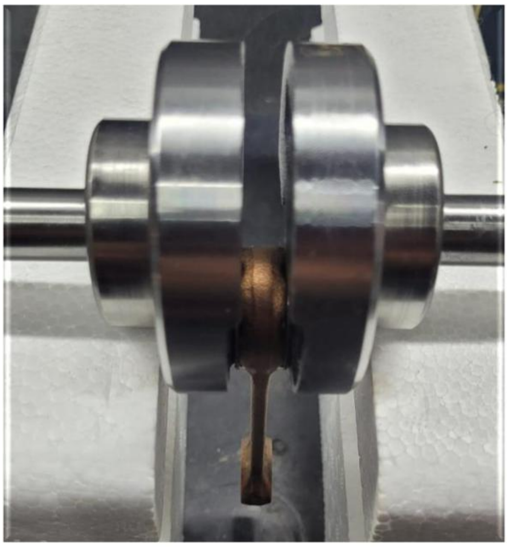
The second step is to weigh the complete piston assembly with rings, pin, circlips and upper cage along with the connecting rod again and record this value.

The third step is to determine how much weight is needed to balance the crankshaft, whether by adding weight to the connecting rod or to the opposite side. You need to add weight to the connecting rod until it becomes static and stops rotating—that is, it should stop in any position without rotating with the extra weight.



Returning to our example, I usually use the crankshaft bearings themselves to support them on two bases. This way, the crankshaft can rotate and show its balance.

In the case of this crankshaft, it's heaviest at the connecting rod, meaning there's no way to add weight to it, since the greater weight is concentrated there. You can see the connecting rod pointing downward, and whenever you try to turn the crankshaft, it stops in that position. But we need to figure out what negative weight is acting to include in our calculation.



To figure this out, I use magnets and add metallic materials to it to find the weight needed for the VB to be stable and stop in any position. Here you can see that the addition was 6 grams.

Knowing all these values, we can calculate the balancing factor as follows:

Connecting rod weight: 32g

Connecting rod + piston weight: 111g

Extra weight: -6 (here the value is negative because the weight was added to the side opposite the connecting rod. If the weight had been added to the connecting rod eye, it would be positive)

So, the formula is:

$$\frac{peso\ biela + peso\ extra}{peso\ biela + pistão}$$

$$\frac{32+(-6)}{111} = \frac{26}{111} = 0.23$$

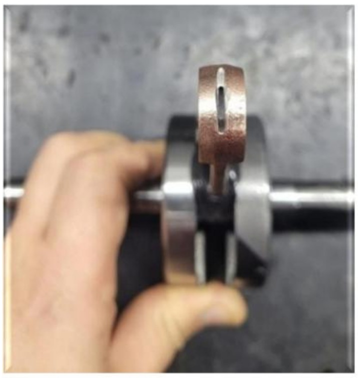
Therefore, the balance factor of the current assembly is 23%. In other words, it's way off. To begin the balancing process, I isolate the lower connecting rod bearing to prevent contamination with metal particles that could damage the bearing.

This step is extremely important because the bearing can crush these particles that get stuck in the lower pin and come loose after the engine is running, in addition to damaging the bearing needles, so be sure to isolate them.

To correct the balance factor, we must add weight to the opposite side of the connecting rod to increase it. I usually lighten the connecting rod a bit when possible, and this is the case here, since this engine will be built with a 50cc displacement and the connecting rod won't be as heavily stressed. I use a flap disc, which is a type of sandpaper, and remove material carefully to avoid overheating the connecting rod and losing its tempering.

But I just align the sides and practically erase the markings. Removing too much material can weaken the frame and eventually break it. If the engine is heavily tuned, I recommend not doing this, as the weight reduction is minimal.

I take the opportunity to open the lubrication slot for oil to enter the upper cage, as this connecting rod did not have one. Like the Dremel cutting disc, I open the slot very carefully and constantly cool it in water to prevent the connecting rod from overheating and losing its temper.



Next, I'll get to the actual weighting part. The correct approach would be to use tungsten, which has a specific gravity of 19.3 g/cm^3 versus steel's 7.8 g/cm^3.

In other words, it's much heavier than steel and makes a big difference in balance.

However, it's very expensive and difficult to work with, as cutting it requires diamond wire, and this specialized work is quite expensive. Therefore, I use lead, which has a specific gravity of 11.3 g/cm^3 and is extremely cheap and easy to work with.

I start by marking three holes and using a small-diameter drill bit, I start the holes. Then I drill to the final diameter with a larger drill bit. Here, I used a 10mm drill bit for the final hole.

Then I increase the internal diameter of the hole but only in the internal part of the hole so that the lead occupies this space and does not come out of the hole after it has been melted and covered the place where there was steel.

Then remove all the chips from the holes and secure the crankshaft level.

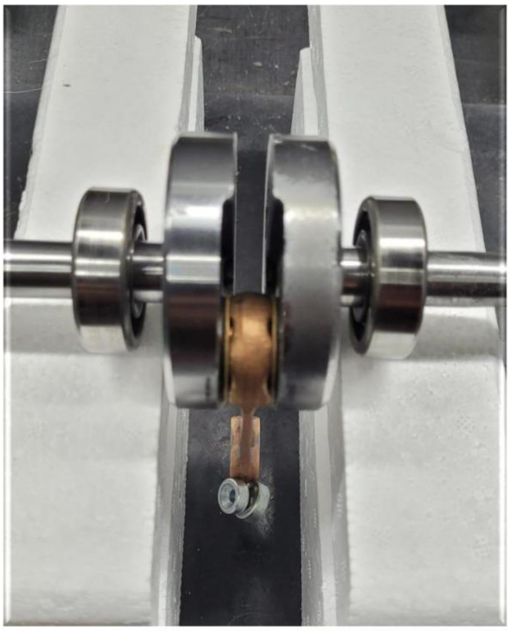
Using a gas torch, I melt lead in a spoon and fill the hole by hole, always ensuring the lead is liquid enough to fill the entire hole. You can easily melt the lead on your stovetop, but be very careful not to burn yourself.

The next step is to tap the lead to remove any bubbles or voids and ensure it fits snugly in the bores. Remember that the crankshaft is sensitive to impacts, so don't hit it hard, as the lead is soft and will mold itself with little effort.

The final step is to remove excess lead from the lathe. If you don't have one or don't have access to one, you can carefully grind away the excess lead.

After the work, we'll retake the measurements and determine the new balance factor. You'll see that the reduction was only 3 grams compared to the unworked connecting rod.

Now we'll check the weight needed to stabilize the crankshaft. This time, it was necessary to add weight to the connecting rod to keep the crankshaft stable and from rotating. The added weight was 9 grams, and this time, this value will be entered as a positive number, adding to the connecting rod weight.



With the new values, we can calculate the balance factor again:

Connecting rod weight: 29g

Connecting rod + piston weight: 108g

Extra weight: 9g

Therefore:

$$\frac{peso\ biela + peso\ extra}{peso\ biela + pist\tilde{a}o}$$

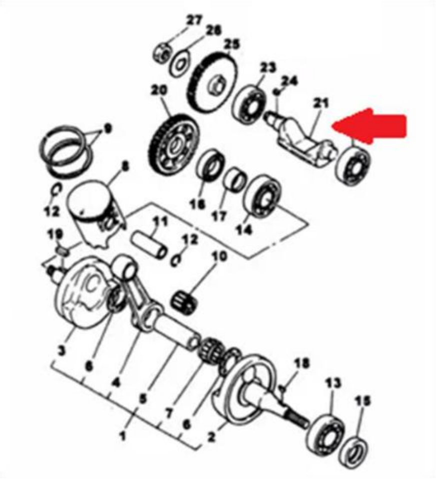
$$\frac{29+9}{108} = \frac{38}{108} = 0.35$$

Therefore, the balance factor of the assembly was 35%. It's still incorrect, but the motor will still vibrate less than it would if the work weren't done. Remember, vibration generates losses.

As we've seen, calculating the balance factor is very simple, but changing it isn't so easy unless you remove a lot of material from the crankshaft. This is especially true for engines with large, heavy pistons.

Therefore, some manufacturers have chosen to make this correction with an additional shaft that has counterweights, called a balance shaft.

The DT200, for example, has this shaft and it makes all the difference in terms of RPM range and comfort, as it drastically reduces vibrations.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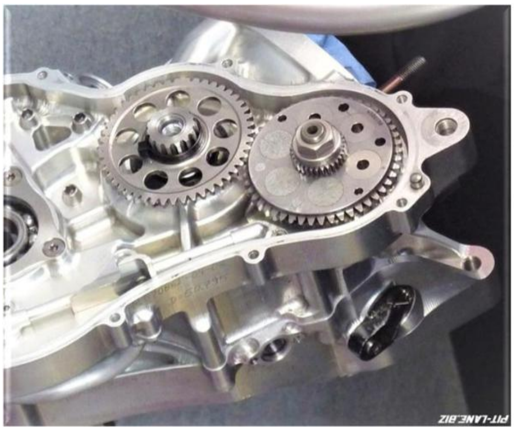
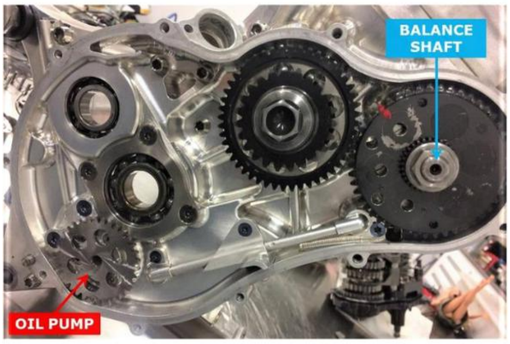
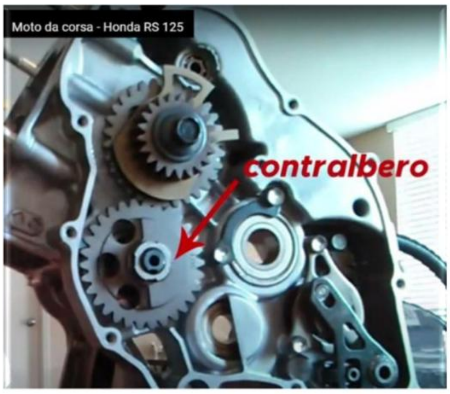
The KR150 also has a balance shaft .

Aprilia RSA balance shaft.





Honda RS125 balance shaft.



Chapter 16 – Ignition

16.1 Introduction

Ignition timing in two-stroke engines can seem like a mystery, especially when you don't understand its fundamentals. However, when you understand its concepts in depth, you begin to understand why it behaves so differently from four-stroke engines, using more advanced ignition timing at low RPM and less advance at high RPM.

like combustion chambers, with no squeezing. Therefore, the flame's reach is enormous, requiring ignition advances of around 50 degrees, even in the highest torque zone. This would be disastrous in a two-stroke engine.

We must first remember that two-stroke engines achieve their peak power when creating and receiving the shock wave. At lower RPMs, the shock wave arrives too early, and at high RPMs, it arrives too late. It makes sense to think that if we could change the speed of the shock wave, we could improve power, right?

However, to change the shock wave speed based on RPM, we would need to change the exhaust length in real time, but this is somewhat difficult to do in practice.

We also know that the speed of sound (the speed of the shock wave) is constant. But we also know that it can vary with temperature. The hotter the gases, the higher the speed, and the colder the speed, the lower.